A MECHANIC ON THE "MECHANISM OF THE BRAIN."

FOR many years it has been evident that our bodily organs, our kidneys, stomachs, toe nails, are complicated mechanisms of the same type, though of vastly higher degree, as storage-batteries, engines or other mechanical manifestations of physical and chemical laws. General physiology has made marvelous advances in recent years, in explaining many of the details of the identity. Extension of these ideas to mental processes has been made by some psychologists and by some mechanistic philosophers. These ideas have not, however, gained the currency which they should and are by no means as universally admitted as they should be.

Furthermore, there is a vast gap in all analyses of the mental mechanism with which I am familiar, between the furthest advance which physiology has made in actual analysis, and the study of the actions of the complete machine with which most psychologists and philosophers begin. I am neither a philosopher nor a psychologist nor a physiologist, but am familiar with the grosser forms of machinery and have had experience with the analysis of material mechanisms. I feel that my point of view is useful in such analysis of the mental mechanism as will fill up the gap mentioned, as well as in the giving of more currency to mechanistic methods and elimination of "psychical" things beyond the domain of physiology.

I have tried to be very conservative, to be tolerant of other view-points in the matter, and to be duly judicial in all of the discussion. I feel, however, that the future will show that much more radical statements are justified.

I. INTRODUCTION.

The Vast Difference in Scale of Natural Phenomena.— As a beginning, we emphasize the commonplace that difference in degree does not necessarily mean difference in kind. The undisputed fact that the operation of the brain is complex beyond all conception does not of itself prevent us from putting it in the same class with the vastly simpler mechanisms whose operation we relatively understand. For instance, we can lift and form a conception of small masses. We can build cranes and lifting-mechanisms which handle masses weighing many tons. We can learn of the vastly greater mass of some of the planets, or of our own sun. We can read the astronomer's accounts of other suns with still greater masses. The ratio of the mass of such a sun to a mass which we can lift is a number with such a long string of 0's, that we have no conception of it. There is a similar situation in the descending scale as we go from a mass which we can lift to individual crystals, to molecules, to atoms and to electrons. Yet the mass of an atom is the same sort of thing as the mass of a distant sun even though there is a difference in degree beyond all conception.

We can measure and have an intimate knowledge of an inch or a foot, and can have a vague idea of the distance to the moon. There are successively greater distances to the planets, to the fixed stars, and to other stellar systems, distances which light travels in a hundred thousand years. In the descending scale there are the thousandths and ten-thousandths of an inch which a mechanic can measure, the lengths of light-waves which a physicist can measure and the interatomic distances which a physicist can compute.

The ratio of the least of these distances to the greatest is again a number beyond conception, yet they are of the same kind and differ only in degree.

The machines which we know and can understand have enormous differences in complexity. A person not versed in mechanical matters has intimate knowledge of simple machines, such as a can-opener, or a crow-bar, but no real working knowledge of such a machine as a clock. Farther up in the scale of complexity are machines such as those for setting type and for printing and folding newspapers. The design and construction of such machines can only be handled by persons with great natural ability for the subject and long training in it. Without meaning any disrespect, I venture to say that the average psychologist will grasp with difficulty the intricacies of a modern high-speed newspaper press. A further step in complexity is the cell-system of a low-grade plant. Successively further along in the scale are the organizations of a high-grade plant, of a low-grade animal, of a frog, and so on. There is no reason *per se* why we should assign any other difference than that of degree when we finally come to the human brain.

The intricacies of a modern newspaper press may bear the same ratio to the intricacies of the cell-system of the brain, as an interatomic distance bears to the distance to the farthest misty nebula. We call the latter things "distances" even though they differ in degree beyond all conception. Why may not the former things also be in one class even though they too differ in degree beyond all conception?

Historical Advances in Mechanical Conceptions.—For many centuries our knowledge of the physical world was that obtained by the speculations of philosophers, based upon the gross evidence of our senses. But presently we

found that the earth was round even though it appeared flat to our senses, and that the earth moved even though it looked as if the sun did. We once believed that the lightning was caused by the wrath of the gods and we peopled all nature with spirits. We must admit the possibility that we have been doing similar things in connection with the processes of the mind. We must hold ourselves ready to advance as far beyond the conceptions of mental processes held by the Greek philosophers as we have in the conceptions of physical processes. Just as we have substituted osmosis, cell-chemistry and other elements of a completely mechanical theory for the idea that there is a nymph in every tree, so we must not hesitate, if need be, to make similar advances with higher forms of life.

Aptitude for Studying Mechanisms.—The conception that the earth is round was a difficult one for all but a very few when the doctrine was first promulgated. Even yet the minds of children and of lower races cannot grasp it. It is only because it has been made familiar to us by experience that we entertain it without doubt. Similarly, it is comparatively easy for one who has been brought up with machinery and who has worked with and studied successively more and more complicated pieces of mechanism, to throw over non-mechanical conceptions and to believe that the brain is a complicated machine. I feel that a psychologist in order to give these matters intelligent consideration must have some such mechanical aptitude. The true mechanic has a keen delight in viewing a new type of machine, in watching it perform its various functions and in studying the methods by which it operates. The designer whose brain has given birth to a piece of mechanism has an indescribable pleasure in starting it up for the first time and watching its operations, if it so be that the machine runs successfully the first time. More

often, there is birth travail and painful labor before successful operation is obtained. The glory of the final success certainly equals that described by painters and sculptors who have completed masterpieces. Something of this mechanical point of view must be understood by one who would make progress in the present discussion. The properly prepared mind has no difficulty in taking up the hypothesis that the brain is nothing more than a vastly complex mechanism, and discussing all of the arguments pro and con in a sympathetic way.

In the present study of the mechanical brain we are in the position of a mechanic who must analyze a complicated machine merely by external observation and by examination of the effects produced. It is as if he must explain a printing-press by examination of the external wheels and levers and by seeing the paper fed in and the printed sheets discharged. However, nerve and brain physiology is making rapid advances and some day will give us a good idea of the internal brain-processes.

II. MACHINES IN GENERAL AND MEMORY IN PARTICULAR.

Mechanism of Memory.—With a conception of the possibilities of mechanisms and with a mind untrammeled by ancient philosophy, let us begin by discussing the phenomenon called "memory." Somewhere and somehow the brain makes a physical record. In this, as in most other parts of our subject, there is no physiological knowledge as to how this is accomplished, so far as the writer knows. Nevertheless, there must be a definite memorandum of everything we remember, of the nature of a phonograph record. It is easy to make a mechanical theory of the action. An original environment is "perceived" by our senses and some sort of a wave or pulse or other transmitting action proceeds along sense-nerves and directly affects certain brain-cells so as to cause some sort of reac-

tion. The mechanism of the "perception" and "transmission" is not our immediate purpose and will be discussed later. The effect on our brain-cells we call "consciousness," the mechanism of which we also will discuss later. For the present we need merely note that "consciousness" consists of some sort of physicochemical action on brain-cells. That is to say, certain cells out of the vast group in the brain, connected to certain sense-nerves, are oxidized, or nitrogenized, or ionized, or electrified, or made to attract or repel each other, or to have their molecules or atoms or electrons rearranged through electrolysis, or affected in some such way, by the pulse transmitted by the sense-nerves. The exact action is complex beyond all possibility of conception at present. At the same time that the "consciousness" is produced, the pulse passing along the sense-nerves also makes a record of itself, by sensitizing or energizing or creating certain "memory-cells," which record is preserved and stored up.

When the remembrance is later called into action by admission of blood into a particular channel, or expansion and contact of a particular nerve, or some such physical connecting-up of a particular group of memory-cells by association, it simulates or reproduces the sense-nerve reaction on the brain-cells by producing on them a physicochemical action like that produced by the original consciousness. That is to say, we may define "memory" as a stored-up record produced by the sense-nerve pulse at the same time it is producing the physicochemical action called "consciousness," which is later rotated into the field of action or recalled by association, and then simulates or reproduces the effect of the original sense-nerve pulse, which results in reproduction of the original physicochemical action or consciousness. The muscular and other reactions initiated by the original or memorized consciousness we

discuss later and for the present confine our attention only to memory.

Memory does not reproduce an original environment, but does reproduce the mechanical impressions which the environment produced. There are a number of familiar machines which act similarly. The phonograph recorder is subjected to the environment called singing and reacts to it so as to preserve a record which later, when the record disk is inserted, yields "sounds" which impress the atmosphere, our sense of hearing, etc., as being a reproduction of the original particular environments, and which initiate effects such as vibrations of the room walls, pleasure on the part of the hearer, etc., just as the original would have done.

A photographic plate with proper lenses reacts to an illuminated scene so as later, when brought out and held to the light, to yield a picture which impresses the surrounding light-wave medium and our sense of sight as being a reproduction of the original scene. So the sound-waves given out by some one speaking to us are transmitted by the ear-sense and the hearing nerves to certain brain-cells which give "consciousness" of the sounds; as well as to certain "memory-cells." These latter preserve a record which later, when association recalls it, impresses the brain-cells as being a reproduction of the original consciousness of the speaker's words and which can cause us to act as if we were hearing the words. In other words, we "remember" what was said and act as if we really heard the speaker. I say to the servant, "Close the window at once," and he reacts accordingly. The environment produced by the sound-waves of my voice reacts so as to directly initiate certain motions on the part of the servant.

On the other hand, I say to the servant, "Close the window if it rains while I am away." A record is made by his memory-cells. Afterward, if recalled by the presence of rain, the memory-cells produce the same physico-

chemical action on other brain-cells as my direct command would have produced and the motions which close the window are indirectly initiated.

The conclusion sought is that it is a purely mechanical matter to store a record of an original environment, such that there is later reproduced not the original but an effect the same as produced by the original, and which effect initiates reactions the same as did the original. The memory does no more than this, so that it does nothing that cannot be explained on mechanical grounds.

The mechanism of memory has been used as an introduction because it seemed to have the nearest mechanical analogies. Indeed, it might have been admitted by present-day psychologists that storage of memories is a mechanical operation, because of general familiarity with phonographs, cameras and the like, without the preceding discussion. This would not have been the case twenty years ago, however.

Nature of a Machine.—Before proceeding with further examination of the machine-like action of the brain it will be well at this point to define what is meant by a "machine." A machine is an organization which reacts to its environment in a manner governed solely by the natural laws of physics, mechanics, chemistry and the like, as applied to the condition of the machine and the environment of the moment.

The well-known mechanistic philosophy makes the point of the ability of an omniscient being to predict the action of all machines for all time. I am rather vague as to what "omniscient" means so that I do not desire to make this particular point. However, I suppose it may follow from the definition.

The point I do desire to make is that all of the reactions of a machine to its environment are purely matters of

natural laws, some of which we study in our text-books and many of which we do not yet know.

The waves dashing on a rockbound coast form a machine, and the shape of the spray clouds, the form of the billows and the sound of the beating waves, all follow directly from the shape of the rocks, the intensity of the wind and the occurrences out at sea which started the waves, all acting according to the law of hydraulics. There is no reaction other than that produced by these laws of hydraulics as applied to the particular rocks and air and water molecules at the instant.

Our thesis is the demonstration that the brain is a similar sort of machine, of course of extraordinarily complex character. There are various cells consisting of carbon, hydrogen, oxygen and other elements, each minute portion containing billions of atoms and electrons arranged about each other in many different ways. Each atom is a planetary system which reacts on its neighboring atoms according to laws of radio-activity, molecular attraction and what not, so as to produce vastly complex molecules of all kinds which in turn form cells of various types in an endless variety of permutations and combinations. The cells of the brain are affected in various ways by the blood and by secretions from the glands which circulate in the blood and by the sensations transmitted to them from sense-organs, and by the food, chemicals or narcotics which have been taken into the body. These various things oxidize or reduce, or have various physical or chemical actions upon the cells so as to affect them in various ways, and the net result is a thought or a muscular action or the driving of a nail or the writing of a word. I have no doubt that in due time physiologists will analyze all these effects in great detail. Even now we know the ultimate effects of many things on the mind though we cannot yet analyze the exact mechanisms by which these effects are produced.

We know that alcohol has a chemical effect on the brain-cells which produces the well-known mental actions of an intoxicated man. We know that opium produces certain pleasant thoughts. We know that when a female animal is "in heat" the secretions from certain glands cause tolerance of the opposite sex. We know that certain stomach secretions produce nightmare, and so on ad infinitum.

Many modern psychologists will probably admit the doctrines mentioned up to a certain point. For instance, they may admit that a plant is a machine but will claim that something beyond the laws of physics and chemistry separates plants from animals. Some may go a step further and admit that the starfish or sea-anemone or some other lower organization of cells can be explained purely by physics and chemistry but invoke extraphysical laws beyond this point. Still other psychologists draw the line between the brains of brutes and the brains of human beings. I draw no line whatever and will attempt to show that even reasoning is mechanical.

III. PERCEPTION AND CONSCIOUSNESS.

Mechanism of the Perceptive Senses.—Next we will consider the "perceptive senses." In spite of any opinion to the contrary, everything that reaches our consciousness from external sources does so by purely mechanical means. All of the senses, by means of which we learn of our environment, are mechanical systems acted upon by mechanical agencies. Psychologists have made good progress in explaining the initial mechanism of many of the senses. We know a great deal, for instance, about the mechanism of the ear and how a sound-wave, by means of the apparatus of the inner and outer ear, starts the pulse along the nerves between the ear and the brain. Similar progress has been made with some of the other senses. The point I desire to make here is that all of our thought originates

in a mechanical way. The music-lover who is thrilled by a symphony had all of these feelings created by compressions and rarefactions of the atmosphere extending from the musicians to his ear. The rhythm and color and the beauty of the music are nothing more or less than the way in which the sound-waves follow each other, the number of different types of vibrations or harmonics produced at the same time, the relative intensity of these different harmonics, the speed or change of speed at which they are produced, and so on. There is no mysterious communion between the soul of the musician and the soul of the hearer, but simply a great number of sound-waves produced as a result of long technical experience on the part of the musician. A good violinist has no more soul than a poor violinist. He simply knows how to bow his strings so as to produce sound-waves which go faster or slower or have more harmonics, etc., so as to affect the ear-drum of the hearer in a slightly different way. There are many who do not thrill and have ecstasy when they hear a good musician. This means either that the mechanism of their ears is not fitted to react to all of the complexities of the sound-waves, or else that the brain-ends of the ear-nerves do not communicate the same impressions to the various brain-cells.

A picture-lover, who receives inspiration from a sunset or from the painting of a great artist, merely receives on his retina a number of bands of color, transmitted by a very complex system of light-waves from all parts of the scene. The entire perception is mechanical and not etherial or mysterious.

The "sense-nerves" or "perceptive nerves" or "afferent nerves" are those which convey pulses to the brain. They are the avenues of "incoming messages." The occurrences at the beginnings or other sensitive centers of these nerves, we define as the "environment." This environment may

be light-waves of various sorts, sound-waves, chemical or mechanical effects of various sorts affecting the "tasting nerves" of the tongue, gaseous actions affecting the olfac tory nerves; heat, cold and mechanical effects which affect the touch-nerves; position which affects the equilibrium-nerves of the inner ear, and other agencies whereby that part of the universe distinct from a being, has an effect which initiates a pulse which is transmitted to the brain. We also include in the environment the perceptions of nerves with internal termini or sensitive centers, such as hunger or satiation of the stomach, the effects of inflammation, abscesses and other internal evils, the effects of toxic products of exertion called "tiredness" and other similar effects whereby occurrences internal to the being are transmitted to its brain. The pulse along the perceptive nerves produces a reaction in the brain-cells at the nerve-extremity which we call "consciousness" and which is next discussed, as well as "memory" already discussed. Mention has often been made of the similarity of this nerve-transmission cycle, between perception and consciousness, to telephone or telegraph or wireless systems. The mechanical nature of both perception and nerve-transmission is generally agreed to.

Consciousness. — The pulse at the brain end of the nerves next causes a brain-cell reaction. A further step is often discussed, the transformation of these cell-reactions into "ideas." There is, however, no reason to postulate any transformation. That mechanical reaction produced on the brain by the pulse from a perception is itself the idea and the matter goes no further. The same perception produces the same mechanical reaction every time, and is the thing we associate with the environment which produced the perception.

A certain environment produces "cold," and after perception and nerve-transmission, brain-reaction of a certain

type occurs. This is the symbol or representation of the cold and is its ultimate effect.

By means of the memory we identify this with previous reactions of the same kind. The kind of reaction in question together with the memorized association with similar previous reactions is the entire substance of our "idea" of cold, and there is no further mental or superphysical process or transformation. When we view a scene with the eye, our outer eye mechanism makes an image on the retina. This part of the process we well understand. We have even made photographic cameras which are good models.

The image on the retina affects countless nerve-ends and is transmitted to countless brain-cells. The resulting group of vibrations or cell-actions or whatever other reaction occurs, constitutes the ultimate mental effect of the scene.

Hence we define "consciousness" as the mechanical or physicochemical reaction produced on the brain-cells by the sense-nerves as the net result of sense-perception of an external environment, and symbolizing or representing it. There is no further transformation to which the term can be applied.

There are many mechanical analogies to this conception of consciousness. A rock lying on the ground reacts to its environment and to occurrences which go on in the world around it. If it is hit with a hammer, vibrations are set up and the fiber of the rock moves to and fro through a slight amount, as is made manifest by the sound-waves. If the sun shines on the rock its parts react in a way which we call "rise of temperature." If a sufficient force is applied the rock moves from one place to another. So in many ways various occurrences in the world surrounding the rock affect it and are "perceived" by it. Is there any difference except a vast one of degree, between these reactions or perceptions and the perceptions of the

human brain to occurrences round about it? Part of the difference in degree is the immeasurably complicated mechanism by means of which the perceptions are received and transmitted to the ultimate brain-cells, as compared with the crude system of the rock.

IV. OUTLINE OF THE MECHANICAL BRAIN.

Philosophers, Mechanists and Vitalists.—At this stage of our development of the conception of a "mechanical brain" it will be well to consider its relation to the old debate between mechanists and vitalists.

A mechanist must of course have some such conception of a mechanical brain as is here presented, but a vitalist might also admit it. Presumably a vitalist has no repugnance to a mechanical kidney, where the entire operation is a matter of chemistry and physics of the various cells and juices and secretions, after the process is once set in motion. From this same point of view a vitalist can tolerate our mechanical brain whose cells and secretions are subject to similar purely physical and chemical laws after the operations are once started. Presumably a mechanist must also have some "ultimate cause." We can have no conception of a machine which was not made by a mechanic. However, we need not reach conclusions on any such questions. We can discuss the mechanism of the brain without drawing any conclusions in the general philosophical problems of mechanism versus vitalism, ultimate causes and the like. Indeed, such conclusions may be wholly beyond us, just as conceptions of its manufacturer are beyond a printing-press.

We therefore may content ourselves with the admission that we have somehow or other, with an origin which is not our present problem, a "physical universe," which is a system of mechanical, physical and chemical elements reacting according to certain chemical and physical laws.

That is, we postulate, without philosophical discussion, that there is a natural world full of atoms and molecules and cells, reacting according to a fixed code of laws, and external to the thing we call the mind or "brain."

The "mechanical brain" is, then, merely an assembly of molecules in such a world, and is the same sort of thing as a rock or a lake or a glacier or a coconut or a printing-press or any other assembly of molecules reacting upon each other and upon their environment according to the circumstances of the minute, and the code of laws. We discuss the composition of the rock or the theory of the glacier or the action of the kidneys in health and disease without introduction of philosophy of ultimate causes, and the mechanism of the brain can be discussed in the same way.

We can trace the action and interaction of the wheels and cams and levers of a printing-press, without consideration of the ultimate constitution of the matter composing the parts or the fundamental difference between an iron or copper atom or how either atom originated, and without philosophy of any kind.

Similarly we may discuss the physiology of the mechanical brain, and in time learn of its action just as we learn of the action of a printing-press. We can do this without ever raising the question as to whether or not we are so finite that it is fruitless to philosophize more deeply.

We will find that we can account for all of the occurrences without recourse to superphysical or psychical actions. True, the physical and mechanical actions are extraordinarily complex but we will find no reason to suppose that they are anything other than complicated manifestations of laws whose simpler aspects are familiar to us.

Résumé of Mental Actions.—We may now resume our analysis of the brain-mechanism from the point previously

reached where a cell-reaction called "consciousness" was produced at the end of a cycle of mechanisms beginning with sense-perception of an environment.

We have discussed the mechanism of the memory which has power to give reproduced consciousness.

The successive reproduction of past environments by such reproduced consciousness we call "thinking." This action we will examine in detail at a later point. As a result of present and past environments, that is, of the sense-perceptions of the instant and of remembrances called into action by "associations" which we also discuss later, there is produced a resultant consciousness in the cells at the ends of the sense-nerves. When these cells are thereby sufficiently charged or saturated they excite a corresponding combination from an adjacent group of cells at the ends of muscle-nerves carrying "instincts" and "habits," and we have an "impulse" to act. This effect we also consider in detail later. The instinct- or habit-cells, when they are thus excited, act on the attached muscle-nerves, which transmit a pulse to certain muscles. These then execute that action which corresponds to the excitation of the particular instinct- or habit-cell combination. We here only mention the relation of these actions to each other as an introduction to detailed study of each of them.

We pause for a brief and final mention of the "muscle" or "efferent nerves" which transmit pulses or "outgoing messages" from the brain and which cause such chemico-physical actions at the nerve-ends as produce muscular motion. It is generally admitted without question that the entire action is mechanical so that we need not devote time to this point. The action is more or less similar to that of the pulses along sense-nerves already discussed and has similar mechanical analogs, such as telegraph or telephone transmission.

The important point which we propose to demonstrate is that the "impulse" to act is a purely mechanical correspondence of a certain one of the untold millions of possible combinations of reactions of the cells at the ends of the incoming nerves which carry consciousness, with one of the equally numerous combinations of reactions of cells at the brain-ends of the outgoing nerves which initiate action.

A very crude analogy is the "player piano." In it, the environment consists of the rate at which the music roll is fed, the adjustments for intensity of the sound and the various other manipulations of the operator. These with the record made in the past, represented by the perforations of the music roll, and corresponding to memory, cause a combination of conditions remotely resembling consciousness. This combination initiates an effect on a certain combination of mechanisms which results in the sounding of a musical chord. There is a remote resemblance between such an initiation and an "impulse"and between the sounding of the chord and an "action."

Another analogy is the "relay" often used in machinery. An incoming effect, such as the motion of a governor in a steam-engine, or a long-distance telegraph message, is not itself transmitted, but serves to actuate the relay mechanism, such as the application of power to the engine-valve mechanism or the telegraph relay-sounder, and this relay mechanism then performs such action as corresponds to the original excitation and the relay structure.

The brain-cell system which receives the impulse from a consciousness and which starts a pulse along the muscle-nerves has an inherited structure which inevitably produces certain actions called "instincts." Through the influence of environment, other actions called "habits" may be "learned." We proceed to the detailed discussion of these matters.

V. INSTINCTS AND HABITS.

Instincts.—A man or other animal which is born with the brain-cells which perform the cycle just outlined, has what are called "instincts" to perform certain acts under certain circumstances.

As an introduction to the discussion of this matter, consider the systems of cells which constitute the hairs of a leopard. The prehistoric leopard was born with a nucleus which, with proper nutrition, grew into a certain hair system. Then the wonderful occurrences of evolution, such as the "law of natural selection" and "survival of the fittest," began to take effect. Thus a system of hair-cells was finally evolved which is either neutral or helpful to existence. Each modern leopard is born with an evolved nucleus which inevitably grows into a general hair system resembling that of all other modern leopards but nevertheless having individual peculiarities. There are spots, whiskers, down, etc., each hair of which is itself a universe of living cells.

The hair system automatically reacts to its environment in a simple way, growing when the root-cells are nourished, falling out when diseased, varying with temperature, etc., all inevitable results of natural laws applied to the cell-system.

A more complicated cell-system is the digestive apparatus of the leopard. This, too, was evolved according to natural laws so as to give a system whose reactions to environment were better and better adapted to maintain the existence of the leopard family. The secretions and juices of the stomach and other digestive organs and all of their operations are automatic, mechanical reactions to environment, the inevitable result of the pressure and chemical actions of food, and other environmental conditions, on the existing cell-organization.

Furthermore, the entire digestive organization and its reactions, complicated as they are, are entirely the result of evolutionary processes.

A further step in complication of cell-organization is the system of brain-cells which determines the "instincts" of the leopard. When the stomach-nerves have the environment of satiation, warmth, etc., and when the general environment gives the complex condition "contentment" the leopard gracefully rolls over and lazily curls his paws in a well-known manner. There seems no reason for assigning any other cause for these actions than automatic cell-reactions to environments, of the same kind as in the hair system or digestive system, but of greater complexity. Similar remarks apply to all other actions commonly called "instinct."

A chicken hatched in an incubator, and raised by itself in a brooder and never seeing another chicken, so that it has no means whatever except "instinct" of conducting its life, will scratch, drink, set and mother a brood of new chicks just as its ancestors did.

Such considerations lead us to define an "instinct" as the brain-reaction which is the inevitable mechanical consequence of an environment on the evolved brain-cell organization. Each instinct is in process of definite evolutionary development just as is any of the other cell-organizations of an animal. Much of this is probably admitted for animals, and the extension here made is to many of the so-called mental processes of the human brain.

As we have defined it, an instinct is essentially an "inherited" mental process. In addition, as already remarked, the brain-cell organization is subject to change, resulting in "acquired" mental processes called "habits" which are discussed later.

We postulate that the brain-cells which carry instincts and habits and which are at the ends of the outgoing or

muscle-nerves, are an entirely distinct set from the consciousness-cells at the ends of the sense-nerves.

Men who hunt or fish for pleasure retain instincts evolved during the prehistoric period when such instincts preserved existence. Many instincts (as for instance that desire to subject the ear-drum and connected nerve-system to certain complex air-waves, called "love of music") are probably neutral so far as preservation of existence is concerned.

All instincts are transmitted according to the laws of heredity studied by Mendel and his successors, in a perfectly mechanical manner. That cell-organization of parents which produces a given instinctive action when aroused by consciousness due to a given environment, is transmitted according to the same mechanism as governs the transmission of the characteristics of sweet peas or fowls.

A "prodigy" performs certain acts, such as arithmetical feats, with extraordinary facility without instruction. The fact that the process is entirely automatic and instinctive indicates that it has some sort of mechanical nature. So far as I know there has not been sufficient psychological study of the matter to even indicate the nature of the mechanism. It is probably some sort of an instinct as above defined.

Reflex Actions.—This term is used by different psychologists to cover quite different regions. There are often included various effects of environment which are relayed by brain-cells. These are covered by the "instincts" just discussed since relaying by a central brain is the distinguishing characteristic.

Blushing and certain sexual effects are often called "reflex actions." However, they may be caused by stored memories of environments, as well as by original environ-

ments, which means that a central brain participates. Hence they are properly "instincts" as we have defined them.

We have already demonstrated the mechanical nature of "instincts," and the same remarks apply to any instincts which may be termed reflexes.

There are also nerve-centers, "ganglions," and the like in various parts of the body which receive incoming nerve-pulses and deliver outgoing ones without transmission to a central brain. There are thereby produced beating of the heart, breathing, digestion and the like.

The term "reflex actions" is often limited to these cases. As the brain is the only organ which stores remembrances, effects such as these in which the brain does not participate, cannot be produced by memory. Such effects are obviously mechanical and they need no further discussion.

Habits.—The organization of brain-cells at the ends of the muscle-nerves, which carries our instincts, is not immutable, but varies from time to time. The reactions produced by the consciousness of a given environment depend upon the exact condition of the mechanism at the instant. There are well-known temporary changes produced by the toxic effect of tiredness or illness, the stimulation of joy and the like. There are also more or less permanent effects produced by education which are popularly called habits.

The brain-cells in question, when excited by a given consciousness, may from any temporary cause react in a certain way, resulting in a certain action often more or less circumstantial. The way is then paved for an easier performance of the action when the same consciousness arises a second time, and so on. Presently some sort of growth is established and a habit is formed. Then the cells at the brain-ends of the sense-nerves will as a result of a given consciousness and the impulse it causes on the cells at the ends of the muscle-nerves, finally produce a

definite muscular action called habit. There are a number of ways in which habits are formed.

Firstly, there is the training or education of a rudimentary instinct. The environment of a being may be such as either to wholly extinguish such a rudimentary instinct or else to develop it so as to result in the formation of a definite habit. Examples are various aptitudes for handling capenters' tools or machinists' tools or for playing certain musical instruments, the tracking or capturing of prey by certain breeds of dogs, and the living of a wild life by a domestic animal when occasion demands.

Secondly, there is formation of habit due to "imitation." As already explained, an instinct is initiated by the effect of a certain environment on the perceptive senses. An "imitation instinct" is initiated when the perceptive senses are impressed by the performance of a certain action by another being. For instance, the brain-cells of a parrot are so constituted that the impression produced by speech upon its hearing nerves initiates a rudimentary reproduction. Continual repetition gives facility and soon the parrot repeats a certain set phrase. Exactly similar considerations lead a human infant to imitate various acts of those around it, so that it learns to walk, talk and otherwise conduct itself.

Thirdly, there is formation of habit as a result of repetition of actions originally initiated by a consciousness which is due to a present environment as well as to remembrances which the environment has called up. The repetition of such actions educates the muscle-nerves in such a way that eventually but little memory effect is needed and the action is initiated almost wholly by environment. An example is the playing of the piano. The meaning of the notes on the staff, the appearance of the fingers when in the correct position, and other details are memorized. Then the effect on the eye nerves of a bar of music together with associated

remembrance of the instruction, cause the fingers to play the bar. The necessity for the joint action of both direct and memorized consciousness causes more or less hesitation at first. Presently the memory is not needed and the bar is played in an offhand manner, merely from the effect of the environment of the presence of written notes before the eyes. That is, the habit of playing by sight is acquired.

A fourth way in which habits are formed is by repetition of a cause which is accidental so far as the being is concerned. An example is the training of the young, or the training of an animal to do tricks. Through some device or other of the trainer, a given action of the subject is caused to occur in connection with a given environment. Thus, a dog without any reason so far as the dog is concerned, jumps when a hoop is presented by the trainer. Repetition devised by the trainer soon establishes the habit.

A juggler, by some trick of the muscles, executes a certain feat and after patient trial successively repeats it until a habit is established.

Important items in the establishment of habit are the juice-secretions or other physical effects on the whole organism which we call pleasure and pain. Certain environmental conditions stimulate some sorts of mechanical action, either with different individual characteristics or with excess and deficiency of a single sort of thing, and then there arise conditions popularly said to be pleasant or painful. For present purposes the only characteristic of this action which we need to consider is that pleasure serves to deepen the traces of any habit effects with which it is associated. There is some sort of a fixation effect on any habit impressions which have recently been made.

An example is the familiar experiment in animal psychology where a caged animal must perform a certain action, such as raising the latch of a trap-door, in order to obtain food. The general excitement produced by the unpleasant-

ness of hunger produces actions of all sorts and presently the trap-door is accidentally opened. There is a faint trace of the accidental action which is at once deepened by the ensuing pleasure and a habit is begun. The same thing occurs again with a slight bias toward the correct action. Soon a permanent habit is established. Similarly a child whose hand is in a hot place is impressed by the action of withdrawal, and soon establishes the habit which we term "dreading fire."

Mechanism of Instinct and Habit.—As remarked in the preceding descriptions of these actions, instinct and habit are properties of cells at the brain-ends of the muscle- or outgoing nerves. When these cells are acted upon by an impulse due to the condition of other cells at the ends of the perceptive or incoming nerves called "consciousness," arising directly or through memory, the muscles mechanically perform an instinctive act or act of habit.

Instinct, as a matter of definition, is inborn. A point also to be emphasized is that the nucleus of each habit is inborn also. The effect of education has already been considered, but it can only develop an inborn rudiment. The kind of action of a muscle of course depends on the condition of the mechanism which in turn depends upon the initial inheritance and the subsequent alteration by environmental conditions. We are so used to performing all of the actions of daily life that we may be inclined to think we do these things because we want to, but close analysis will show that we do them as a matter of habit. We are born with a few instincts, such as to cry and to suckle, and we learn by great labor to talk, walk, dress, use a knife and fork and the like. If occasion arises for performance of any unusual action, such as the tying of a complicated knot by a person not used to such matters, or even the use of the left hand, or the ring finger, for a purpose for which

it has not been trained, we make use of such habits as may have been acquired, and move the fingers in a clumsy way. No amount of will or so-called reasoning power will enable us to perform the action the first time. We perform it first as a matter of accident while thus groping around among the habits already acquired, and can only perfom it with facility after that education called practice.

These considerations seem to me to establish beyond question that instinct and habit are mechanical effects. The crude analogies of the player piano and the relay mechanism have already been mentioned. The exact action initiated by the consciousness arising from given environmental circumstances, whether due to instinct or habit, is the result of the evolved condition of the brain-cell system as already considered. The differences between the actions, habits and instincts of different human beings, or of human beings and animals, are of the same nature as the differences between their skins or skeletons or any other set of physical characteristics. As already remarked, the passage of excitation of some sort from cells at the ends of sense-nerves to cells at the ends of muscle-nerves we have called an "impulse," and this we will discuss in detail later.

It is to be noted that we postulated that memory and habit are wholly different things carried by different sets of cells connected respectively with the incoming or sense-nerves and the outgoing or muscle-nerves. We remember an environment due to reproduction on the sense-nerve cells of the effect of the original environment. We do not, however, remember how to walk or to button a coat, but have learned to do these things through the mechanism of an entirely different set of cells. Amnesia is loss of memory due to derangement of the corresponding cells and does not affect the habits. Paralysis is loss of power of the muscle-nerves and does not affect the memory. Frequent cases of amnesia are reported where a subject loses

power to recall stored remembrances due to a disconnection of some kind in the brain-channels. In such cases the habits are not affected and the subject can walk, talk and conduct his life. On the other hand, after some kinds of illness, a patient must learn to walk or to resume similar habits. It is considerations such as these that have led me to postulate that habit and memory are properties of entirely distinct cell-groups.

Most of the organs and cell-groups of the race have been evolved in identical form for both the male and the female sex. There are, however, certain organs and glands with sex distinction. The secretions from these may cause different actions of originally identical organs. It seems probable that the entire mental organization of brain and nerves, consciousness, memory- and habit-cells, is identical in both sexes. The secretions of those sex organs which are different give chemicophysical actions on the brain-cells which cause whatever differences there may be between the aptitudes, tastes, affections and natural instincts of males and females of equal rank in evolution and development.

VI. THOUGHT.

Association and Ideas.—The effect of association in bringing remembrances of past events into play has already been alluded to. We define an association as the action whereby the consciousness of a present environment recalls the stored memory record of a past consciousness so as to renew it. The memory of an event may remain for years as dormant as a phonograph record stored in a cabinet, but when the proper association brings it forward, it renews the original consciousness in a way more or less similar to that caused by a present environment perceived by the senses.

A consciousness due to a present environment recalls a past environment which is similar. A consciousness due

to such a recalled environment in turn recalls a past environment which is either similar or which was memorized at a time near to that of the recalled environment.

As an example, I have just looked at an electric light, and this recalled an incandescent gas light, which in turn recalled a gas plant in Philadelphia and a certain brick building in the plant.

We need spend no time in discussing the wide range of things covered by the term "similar" which are recalled by memory association. There are, of course, a thousand things similar in various ways to a given environment and any of them may be recalled. In many cases there is recalled a composite group called an "idea," which combines many similar elements from past experience.

For instance, I have recalled the sounds making up the word "statue." This in turn recalls the definition of the word, with many shades of meaning, some particular statues, the use of the similar word "stature" in speaking of the shape of a man, and many other things comprised by the idea of statue.

Each time an idea or some element of one is recalled, something is added to it, either in the way of enrichment or intensification. All of the related elements comprising a composite idea are stored together in some way, just as related items are recorded on a single card in a card-index file or as related papers are kept in a pigeonhole. The association tie recalling the idea rotates this pigeonhole to the front, some or all of the elements of the idea come to our consciousness and a new element, due to the present environment which caused the recall, is added to the things already in the pigeonhole. The pigeonhole is then pushed into the background and may not come to the front for years.

When an idea is recalled, there may also be recalled things not a part of the idea, but which were memorized

at the same time as were some of the components of the idea. Thus the idea of statue recalls to me certain public gardens surrounding a certain statue and the pleasure boats in the garden. Each memorized thing is thus associated with a multitude of other things by some sort of ties, both of similarity and of contemporaneity. A type-setting machine forms a very crude analogy. A multitude of matrices are stored away, and one comes to the front when the proper mechanism operates to call it out. Here there is, however, nothing analogous to the addition of a new element to the thing recalled. Association thus fastens together all of the vast number of ideas or remembrances of past events with a multitude of ties, each idea linked to a thousand others by some sort of similarity, giving a network complex beyond understanding.

As each idea is remembered, it actuates some one of the thousands of links connected to associated ideas and another idea is remembered. The present environment has some influence or other in determining which other idea is brought forth. The fact to be emphasized is that successive ideas do not come forth arbitrarily but always due to some sort of mechanical connection. The association ties are real links of some mechanical sort acting just as definitely to bring forward the associated ideas as do the compressed-air connecting pipes of the type-setting machine. In testing subjects by Binet-Simon methods, one almost sees the mechanical nature of association links.

Our various ideas are more or less deeply "impressed" on our memories. This is, of course, a purely mechanical action whereby the chemicophysical effect which produces the memory record takes place in a more vigorous way so that association ties bring it to mind more easily.

Ideas are of very diverse kinds. Some are results of manifestations of natural phenomena, such as gravity. We see falling rocks or fall ourselves in childhood. We are

later told of the "law of gravity" as being a reason why things fall toward the earth instead of away from it. So each successive item is added, and by the wonderful power of association, each attaches itself to the nucleus of the idea already existing, so that it forms part of the resultant consciousness arising from the recall of the idea at any future time.

Some ideas are said to be "abstract," such as "justice" or "mercy." However, there is always a large concrete element and "justice" brings consciousness of law-courts and arrest of burglars and some specific instance of fair treatment. Each element of an idea has been formed by a consciousness arising from sense-perception of a concrete environment and every idea consists of a complicated résumé of such perceptions. Of course, an essential part of an idea is its name, and the sounds concerned with the spoken word and the image of the written word, form part of the memory record.

One idea which we have acquired partly from instruction during childhood and partly from actual experience, is the idea of "self." It is often stated that one of the important characteristics of the human mind is its power to have consciousness of itself. However, I do not see that this particular idea is more important or fundamental than a thousand others.

It was comparatively easy to formulate a conception of a mechanical consciousness, since we only need to realize, as already pointed out, that some sort of physicochemical reaction must be caused by the sense-nerve pulse, in the brain-cells at the end of the sense-nerves. It was also easy to make the next step, which is that this reaction at the same time causes a brain-cell formation or arrangement which persists as a memory record. It is, however, much more difficult to formulate the method whereby successive additions to this record are made, of things which cause

a similar consciousness and so are associated together, so as to form the complex cell-organization or arrangement comprising an idea. As already noted, when certain associations recall the idea, there is renewed a chemicophysical action on the cells at the end of the sense-nerves which gives a résumé of the consciousness or original effect of the number of environments which comprise the idea. Thus an idea is a perfectly definite mechanical thing although we are not able to specify the precise kind of cell-arrangement or mechanism which comprises it. I do not believe, however, that the matter is as vague as the conception in the mind of the average psychologist, of the mechanism of our often-referred-to high-speed newspaper press.

It seems to me that the essential difference between the brain of man and brute is the possession of the group of cells which stores remembrances and ideas and recalls them by association. Some of the higher animals might, however, possess the rudiments of such a cell-group. The production of consciousness by environment, the resulting impulse which excites cells carrying instincts and habits, and the consequent muscular actions, seem identical in man and the higher animals. The animal, however, acts only from a consciousness produced by the present environment without influence of stored memories of past environment. As already remarked, we distinguish instinct and habit from memory so that the possession of the latter faculties by animals does not imply the possession of the memory-mechanism. Suppose that a dog has been taught to do a number of tricks, each having a distinct commanding sentence such as "Jump over the chair," "Fetch that stick," "Say your prayers." Suppose, however, that the dog were taught to wait to begin the execution of the trick until the executive command "Commence" were given. I do not believe it would be possible to teach the dog to wait for a period between the commanding sentence and the word

"Commence," if during that time something were done to attract its attention. If the word "Commence" were given immediately after the commanding sentence the dog would, of course, do the proper trick. In this case, the consciousness of the combined commanding sentence and the word "Commence" would initiate the acquired habit as already explained. This consciousness would remain in force until its effect had been accomplished. The attracting of the dog's attention to another thing between the commanding sentence and the word "Commence" would produce a new consciousness. The consciousness of the commanding sentence would then have to be stored or memorized and later recalled by association when the word "Commence" was given. So far as I know no dog or other animal can do this, and this is my reason for believing that animals have no memory. It is probably habit and not a memory rudiment which makes a dog cringe at the sight of its whip.

Thinking.—The train of consciousness effects due to the combination of perceptions of present environments and the successive remembrances of associated ideas brougth to mind by the present environments and by each other, we call "thinking."

Each combination affects our consciousness just as does any new environment and makes a new memory record, so that we remember what we think. If the flow of blood or brain-fluid or whatever lubricates and activates the association processes, is in good working order, and if present environments are not impressive and distracting, we are said to be in a concentrated thought. Then past environments are remembered, each bringing in some other by association, and a net consciousness is arrived at, called a "conclusion" or a "decision." We therefore define a conclusion as the composite consciousness which is the epitome

or summation of a train of successive ideas or associated remembrances combined with some present environment which initiated the association train. It is the net result of the entire combination of environments associated with a given thing, which we call experience. In fact, a conclusion not only represents one's own experience but often the entire experience of all previous human existence. Suppose, for instance, I am designing a machine and must select the size of a minor shaft which need not be found by detailed computation. I have learned "Machine Design" and am familiar with machines constructed by previous designers. I thus have a group of remembrances which represents more or less imperfectly all human experience. A certain amount of this is brought forth by my powers of association, when confronted with the environment of the missing shaft size in the design of the machine I am working on. I thus reach a composite consciousness of a shaft size which my experience has encountered under associated circumstances, and I say that I have "thought out" a shaft size which "looks right."

If I have a brain-mechanism whose association ties for this sort of thing operate well, I reach a good conclusion. In any event, the conclusion reached is purely a matter of the remembrance records stored in my brain, the power of my brain-mechanism to associate the sort of thing in question and the present external environment. There is no reason to seek anything else but a mechanical combination of these effects. True, we have reached a stage of mechanical complexity which we cannot yet grasp, but this is not a reason for introduction of non-mechanical effects. We do not grasp the mechanism whereby a dazzling flower is produced from the black earth and the sunshine and rain, yet we do not doubt the mechanical nature of the entire growth.

Those kinds of environment perceived by the conscious-

ness of an individual, those kinds of remembrances which are stored, the way these are associated with each other to form composite ideas, the way they are recalled by association, and similar circumstances, are dependent only upon the physical character of the brain-cell organization, as evolved through countless generations. The habit- and instinct-cells are similarly evolved, as already discussed. There is thereby determined completely the way the individual thinks in any environment just as definitely as the evolution of the digestive organs determines the reaction to food, or as the evolution of any other part of the body adjusts its reactions.

The Subconscious Mind.—We have concluded that successive remembrances brought to the attention of our consciousness by association, each have, to a large extent, the same status as a consciousness produced by a sense-perception of an environment, and are thus again stored as memory records. In some cases the old record is more deeply impressed. We thus remember when we remember anything. It may happen that such remembrances of a train of associated remembrances are not all deeply impressed except for the final conclusion. Hence we may forget the steps of the train and so far as a permanent record is concerned, only have cognizance of the conclusion. Such an action is said to be that of the "subconscious mind." The belief is common that this subconscious mind operates automatically. However, the theory we here seek to establish is that all of our thinking is done in some such way and that the only difference between subconscious thought and ordinary thought is in the depth of the memory-impression of the successive remembrances brought into action by association. Our theory of the automatic nature of all thought due to successive association, is therefore quite similar to the usual idea of subconscious thought.

The psychoanalysis of Freud has shown that in a great many cases a remembrance of a particular environment has formed the genesis of an idea which has associated itself with such other things as to give it great importance, although the original thing itself is forgotten or recalled with difficulty.

Mechanism of Thought.—Of course, the association ties we have discussed are not steel links which inevitably bring forward a definite remembrance whenever the corresponding key is struck. The extraordinarily complex mechanism which calls forth remembrances, is the cell-system carrying consciousness, in its instantaneous condition due to a combination of the effects both of our environment, as perceived by all of our senses, and of remembrances next previously brought forward. Then there is the physical condition of the various cells involved, and the effect of the toxins, juices, narcotics, stimulants and activators due to tiredness, pleasure, pain, ill health, emotion, vigor and many other similar items. In addition the condition of the cell-system where the memory records are stored further complicates the situation. Different kinds of remembrances are recalled with different amounts of facility by different brains. The association mechanism of my own brain handles mechanical ideas with facility and ideas regarding female millinery with difficulty, while my wife's brain is the reverse. All of the discussion previously given regarding evolution and heredity of the cell-system controlling habit and instinct, also applies to the quite distinct cell-system governing memory association. In this way individuals and races have been evolved which think well in certain directions and the memory and association system itself has been formed. As already mentioned, I do not

believe that animals have the power of recalling past environment by memory. Hence they cannot think.

The depth of the memory-impressions regarding a certain subject, and its importance to us, may cause concentration of thought on this subject, and discourage the presence of varied miscellaneous associations which local environment and the like tend to bring forth.

All of these effects have an influence on the train of thoughts teeming through our brain at any instant. The seething consciousness-cells, alive to the effects of all of the surrounding environment on all of our senses, with each such effect crowding along its train of associations, and each of these carrying a new train, give a thought-mechanism of incomprehensible complexity. Yet there is no reason for supposing that there is any effect which is not due to the matter in the brain-cell organization, its past history as manifested by the state to which it has been brought, and the present surroundings both of the cells in the brain and of the being in its environment, all interacting in a perfectly mechanical way.

The normal brain-cycle involves interaction of many individual parts, senses, nerves and cells. Change in the action of any of the elements gives a variation of the cycle. Thus we may have tiredness, sleep, dreams, automatic writing, trance speaking, delirium, drunkenness, insanity, paralysis, amnesia, hypnosis, idiocy, infancy, age, second childhood, and so on. All of these things have a purely mechanical basis. Sleep may be merely the shutting-off of the pulses from the sense-nerves, so that there can be no consciousness of present environment, but only circumstantial recall of remembrances. Analysis of the mechanism of the mental effects mentioned must be postponed for lack of knowledge. Their study from the point of view of the present paper will give more detailed knowledge of the brain mechanism.

VII. REASON AND IMPULSE.

Reasoning.—There are two forms in which the old conceptions of "reasoning" may be expounded, the definite one of "formal logic" and the rather vague popular one. We will endeavor to show that neither conception gives such an adequate explanation of the action of the brain as is igven above by our theory of recall of remembrances by association.

Formal logic asserts that we think by "deductive reasoning," in syllogisms, with major and minor premises and conclusions. For instance, take the major premise: "All agencies which produce mechanical energy when no mechanical or heat energy is supplied, produce this energy by transformation of chemical energy which has been supplied to them." A minor premise is: "Human bodies are agencies which produce mechanical energy when no mechanical or heat energy is supplied." The conclusion is: "Human bodies produce mechanical energy by means of chemical energy which has been supplied to them." This is a case of the simplest type of syllogism and is of the kind classified by ancient logicians as being in the figure "Barbara."

I have arranged a rather complicated case, so that a little study is required to draw the conclusion, with the idea that the reader's own effort to verify the conclusion will illustrate the mental processes involved. It seems to me that we draw the conclusion solely by means of associations and past remembrances which the premises recall. We have had experience in past cases where a characteristic common to all members of a class is possessed by all members of any group in this class. Any syllogism in Barbara implied or expressed recalls such associations, and they in combination with the particular premises give that resultant idea called the conclusion.

Following are two more syllogisms both classified as being in the mood "AEE" and in the first and second figures respectively. "All M is P. No S is M. Therefore, no S is P." "All P is M. No S is M. Therefore, no S is P." One of the conclusions is valid and one is invalid. I believe the average reader will make some mental effort in determining which is valid and which invalid. In doing this it seems to me he draws only on his past experience, and reaches the conclusion solely by associations with past remembrances of regions which include or exclude each other. The first syllogism above is the invalid one and the second is valid in the mood called "Camestres."

Another example is: "All birds are vertebrates. Some winged animals are not vertebrates." Can the reader reason directly that a valid conclusion is "Some winged animals are not birds"? This is a valid syllogism in the mood called "Baroko." The theory we have advanced implies that there is no such thing as "deductive reasoning," but that all conclusions are reached in the way called "induction." We make comparison with things of past experience which our association ties bring forth as being similar.

Hence there are two ways in which we certainly do not reach conclusions. In the first place we do not use the rules of "formal logic." There was a time when the principles of logic were considered a necessary part of a good education, but this is no longer the case. A person who has never heard of logic can reason perfectly well. Hence it seems evident that the logicians' analysis of reasoning is not the correct one. In the second place, the conclusion of a syllogism is not directly obvious to a reasoning being. I believe this will be admitted by any one not familiar with formal logic who will work on the syllogisms given above.

It is "popularly" supposed that we reason by an infallible process which gives us the absolute truth concerning given

circumstances, and which is beyond any material explanation. I see no basis for such a supposition, however.

One point to be made is that reasoning produces nothing new. A conclusion states nothing which is not implied by the premises. A train of reasoning only brings to our consciousness either an independently existing fact, or else something which past associations indicate to be such a fact. A discovery of a scientist, or an invention of an engineer, are in the ultimate analysis nothing but consequences of associations recalled by brains with extraordinary powers of memory and associative ability. As the association ties are calling each other out in a manner depending upon the conditions of the instant, some circumstantial combination may occur. In a mind rich with associations in a given field, this leads to some more definite train and so a novel idea is originated or an invention made or a natural law discovered. Such things really happen with great rarity and most of our thoughts are rearrangements of familiar things.

Each generation learns the things left by the previous generation and adds a little from such novel associations. Wonderful as our progress it, it is really very slow. Eons ago we gesticulated and grunted. After some ages evolution produced a few brains which associated certain sounds with certain environments, and so speech arose and was taught to others. Next written records were made. Some brain in each of a number of races, by some circumstantial combination of associations made a contribution to these advances. Thus arose different kinds of written records, hieroglyphics, ideographs and phonetic writing. There was no definite system of reasoning whereby the successive advances were worked out. Similarly the different arithmetical systems were made by successive contributions of individual brains. In modern times we are building sys-

tems of physical science, engineering and the like in the same way.

Beliefs and Truths.—When an environment of any kind presents itself to our consciousness, whether the germ of a new idea or something which can be attached by association to a previous idea, it forms some material thing which becomes an essential part of our being. An idea is therefore some sort of cell-formation or arrangement which is of the same nature as a finger nail or a digestive gland. For instance, we have the idea that a body falls toward the earth. Anything which recalls the idea of falling involves consciousness of falling toward the earth. There is a clash or inconsistency of some kind if some one remarks that he saw a table rise from the floor. We say that this is contrary to our belief. Our ideas thus constitute a code of beliefs or things we regard as truths. The important point which must be made is that a belief is not necessarily in agreement with natural laws, that is, not necessarily true, but only represents the net result of things presented to our consciousness in the matter.

There is, however, a system which by definition is uniformly true, and this is the code of natural laws. Philosophers and psychologists speak of the "uniformity of nature," but I do not believe they can have such a keen appreciation of the situation as an engineer or other worker in natural science. A novel type of machine or a new bridge construction or a chemical manufacture on a large scale, operates successfully as the result of the combination in the design, of certain natural laws which were ascertained with small models in a laboratory. We must admit that there exists a code of such natural laws which our finite brains can make use of and by virtue of which we can construct mechanisms, plant seeds and conduct our lives, with cer-

tainty that the final result will depend exactly upon the way the circumstances are controlled.

Our beliefs are true only in so far as they are in harmony with this code of natural laws. Our only means for ascertainment of the validity of a belief is comparison with natural law in so far as we are able.

The evolution of a race depends wholly upon the ability of the brains of its members to conduct themselves so as to exist in the natural world. Hence ability to come to more or less perfect agreement with natural law has been accomplished.

However, we may hold many beliefs which are false, either because we have not compared them with natural laws or because we have made inaccurate comparisons. We have already noted how circumstantial associations of a fertile brain occasionally make a novel combination resulting in an invention or discovery. On the other hand, such a cause can equally well originate a fallacy which, however, has the appearance of truth. By transmission from such a source or by some incorrect combination in our own minds, we obtain such false beliefs. The history of Oriental religions and the history of the beginnings of science show us that men can hold a belief with the utmost confidence which is wholly false. We are loath, however, to admit the possibility that any of our own personal beliefs may be in this class. Yet this is certainly true. "Faith" is the term we apply to our confidence in our beliefs, but it is an uncertain foundation. A certain belief may assist in the evolution of a race and yet be false. Many of the beliefs of ancient and modern religions are false and yet it is conceivable that some may have been of advantage.

The only test, then, of the truth of a belief is comparison with natural law. The mere speculations of philosophers have never led to stable results. Many of the beliefs of scientists, engineers, farmers and others who work with

the laws of nature have, however, been proven true by the success of results of applications of these beliefs. I have certain beliefs in science and engineering and have designed novel machinery based on these beliefs, which has operated successfully. I have by associations of various kinds extended such beliefs to the subject-matter of this article. The extent of the agreement of other observers of natural laws with these beliefs and results of future progress will determine to what extent these beliefs are correct.

We acquire many beliefs from simple statements of others. If the idea involved does not by association recall a similiar idea we have a new belief. If it does recall a similar idea with an opposite conclusion and if we can associate the particular situation with previous general ideas of the impossibility of opposite conclusions, we accept the new belief and modify our idea in the matter, or else reject it, according to previous associations. Thus teachers, exhorters, politicians, preachers, expounders, parents and friends take part together with our own experiences and interpretations of our environments and perceptions of natural phenomena, in giving us a set of ideas and beliefs which are embodied in some sort of cell-arrangement as definite and concrete as the pores in our skin or the hairs of our head.

As an example of the way we reason consider the matter of faith in some religious custom.

In order to avoid the risk of poisoning by a wife, certain Hindus somehow started the custom which soon grew to be an important matter of faith, of burning of widows by suttee. We know that even though many people for centuries had faith that this was a matter of absolute necessity, that it actually was nonsensical. Hence the faith or firm belief of a human being that a certain thing must be so because they feel that it is so, is no reason whatever for supposing that the thing really is so. However, many

people do not associate this general situation with things they themselves have faith in. Others do make such an association and consequently do not accept things on faith.

Impulse and Will.—We have already formulated the hypothesis that cells at the end of sense-nerves carrying a resultant consciousness of present environment through sense-perception and of past environments through recall of remembrances by association, become by virtue of this resultant consciousness so charged or activated that they excite a corresponding combination from an adjacent group of cells at the ends of muscle-nerves carrying instincts and habits, and so initiate an action. This excitation or "impulse" to act corresponds to the "will" of psychology. Our theory of the mechanical brain of course corresponds to the mechanistic side of the old debate concerning free will, and this paper attempts to outline the mechanism involved.

It is not to be supposed that this impule to act is as definite a thing as, for instance, the rotation of a toothed wheel when an intermeshing wheel is rotated. The entire history of the ancestors of the individual as affecting the inherited condition of his brain and the entire history of his environments as affecting the brain's present condition, all have their influence. There are no factors which do not exist either in the brain-cell organization or in those external things to which it has reacted according to the laws of nature. It would indeed be strange if there were any accident or caprice in a universe which we find to be so wonderfully ordered, from the smallest details shown by the microscope, to the mighty things shown by the telescope.

Good illustrations of the dependence we place upon such principles, though we do not realize it, are the teachings and preachings to inculcate ethics, morals and religion by parents, teachers and preachers. By adding to or creating in the brain of the subject some ideas as to the thing

we believe to be "right" under given circumstances, we expect to influence the subject in a given future environment. Our exhortation implies a number of things. In the first place, we expect to create an idea in the mind of the subject which will persist until some future time. Obviously we expect that in the meantime it must exist in some way or other. There can be no magician's act which makes a thing vanish and later reappear from nowhere. Now we know that some kinds of environment, such as warmth, have a definite influence on the cells in the interior of our bodies. We know as well that our words have a definite mechanical effect on the ears of a hearer, and start an actual pulse along the nerves to the brain. But this pulse does not trail off into nothing when it reaches the brain. It seems to me that the hypothesis most readily agreeing with other experiences which we have with natural phenomena, and therefore the thing to be believed, is, as already discussed, that the nerve-pulse finally results in a definite brain-cell formation or arrangement recording the idea in a concrete way. The record is later recalled so as to give a simulation of the effect produced by the nerve-pulses from the sound-waves of our original exhortation.

In the second place, our exhortation implies that we expect that upon proper occasion, the subject will act in accordance therewith. We therefore expect that that condition of the subject's brain-cells which we have created, and not some caprice of the subject, will cause action when the future environment arises.

The extent of the association which a given environment arouses in an individual determines the kind of consciousness which creates the impulse. If there are usually recalled a very limited or superficial set of remembrances, the individual is wilful or emotional. If there are usually recalled deeper and more varied remembrances, the emotions are controlled by reason. However, in all individuals

there are many impulses which are produced by a consciousness only due to present environment without remembrances. Thus we jump when we hear a loud noise and withdraw the hand from a hot place. Such actions we term "instinctive" or "automatic." They differ from other actions only in the type of consciousness which impels them. These are the only kind of actions possible with animals according to our postulate that they have no memory and can only have consciousness of a present environment.

A very crude illustration of the way the impulse-mechanism might operate is as follows. The cells which carry consciousness of sense-perception may lie along a folded surface in the brain on the other side of which lie the cells at the ends of muscle-nerves. A given consciousness consists of expansion by flow of blood or some other form of excitation of a certain combination of the sense-nerve cells. Impulse is the pressure or other effect of this excitation, across the surface, to the muscle-nerve cells, which excites or energizes a corresponding combination of them. This starts the pulse along the muscle-nerves which causes an action.

Thus each group of the untold number of possible combinations of cell-reaction due to sense-nerve and memory effect gives an impulse to that group of muscle-nerve ends which corresponds or matches with it. The correspondence determines that instinct or habit which is called forth in the given individual as a result of given environmental conditions.

VIII. DIAGRAM OF THE MECHANISM OF THE HUMAN BRAIN.

The accompanying figure and explanation gives a résumé of the way my brain associates its actions with the gross mechanisms to which I am accustomed. The application of my own theories to this paper means, of course, that I view this matter from a mechanical standpoint. Time

and study will determine if comparisons made from other standpoints are less accurate.

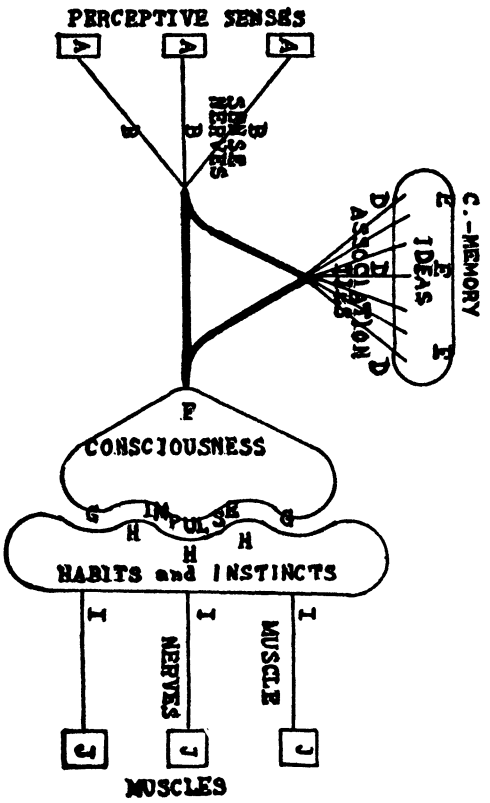

DIAGRAM OF THE MECHANISM OF THE HUMAN BRAIN.

AAA—*Perceptive Senses*: Sight, hearing, etc. Mechanisms affected by various kinds of external environments, forming the means by which the influences of these environments start toward our brain.

BBB—*Sense or Afferent Nerves*: Channels whereby incoming pulses initiated by effects of environment upon the senses are transmitted to the brain.

C—*Memory*: The stored-up record produced by the sense-nerve pulse at the same time it is producing consciousness. When any one of the ideas stored by the memory is recalled by association, it simulates or reproduces the effect of the original consciousness. Possibly the possession of this memory organ is the distinction between man and brute. The memory record exists as a concrete material thing, being some sort of

cell-arrangement or growth, of such kind as will renew the effect of the nerve-pulse which created it.

DDD—*Association Ties*: The means whereby a present consciousness recalls the stored memory record of a past consciousness so as to renew it, due to similarity or contemporaneity. A new element due to the present environment is thereby added to the record.

EEE—*Ideas*: The composite record of similar elements from past experience successively added by association. All or part of an idea is recalled to form a resultant consciousness by an association tie connecting it with a similar present environment. The recall of ideas by associations arising from the consciousness which each one successively produces is called "thinking."

F—*Consciousness*: A physicochemical reaction on brain-cells at the ends of sense-nerves, caused by the pulses from the senses, and constituting the entire result of the sense-perception of an environment. It may arise either directly from a pulse caused by a present environment or from records of such pulses from a past environment stored by the memory or from a resultant of both.

G—*Impulse*: That reaction of the cells at the ends of the sense-nerves, due to a resultant consciousness both of present environments and past ones from recall of remembrances, whereby a certain combination of cells becomes so charged that it excites the corresponding combination from an adjacent group of cells, at the ends of muscle-nerves, carrying instincts and habits.

HHH—*Instincts and Habits*: Reactions of cells at the brain-ends of the out going or muscle-nerves due to excitation by an impulse from cells carrying consciousness. A certain one of the untold number of possible combinations of the instinct- or habit-cells, corresponding to the particular consciousness-cell combination, thereby initiates a muscle-nerve pulse. Instincts are reaction combinations which are inborn. Habits are combinations with an inborn nucleus developed by education.

III—*Muscle or Efferent Nerves*: Channels whereby outgoing pulses initiated by habit- and instinct-cells in the brain are transmitted to various muscles.

JJJ—*Muscles*: Mechanisms of various kinds which perfom all sorts of actions when excited by pulses from the muscle- or efferent nerves.

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